URCHIN – Manually-deployed geo-referenced video system for Underwater Reconnaissance and Coastal Habitat Inventory

M. B. Strong and P. Lawton

Fisheries and Oceans Canada
Biological Station
531 Brandy Cove Road
St. Andrews, NB
E5B 2L9

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Biological Station, 531 Brandy Cove Road
St. Andrews, New Brunswick, Canada, E5B 2L9

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ABSTRACT

Strong, M. B., and P. Lawton. 2004. URCHIN – Manually-deployed geo-referenced video system for **U**nderwater **R**econnaissance and **C**oastal **H**abitat **In**ventory. Can. Tech. Rep. Fish. Aquat. Sci. 2553: iv + 28 p.

The URCHIN video system was designed in 1997, for maximum survey depths of 50 m, to augment SCUBA diver-based field survey methods for detailed descriptions of coastal benthic habitats. Required information products included high quality geo-referenced video (with positional data overlaid on video), geo-referenced log files for benthic habitat classification and biota encounters, and associated depth and temperature data. Functional attributes for underwater video acquisition were a robust, light-weight, camera and frame permitting manual deployment, speeds over bottom of up to 1 knot, and operation in low light and turbid bottom conditions. Functional attributes for the surface survey package were a geographic information system interface for survey design, tracking and navigation, video recording and annotation capability, all within in a self-contained, readily-transported unit for use on vessels of opportunity. Two URCHIN video systems were subsequently assembled and, after initial field applications, a formal survey protocol was initiated in 2001. A relational database (Oracle-based) houses video survey data, and SQL queries have been written for various data extractions. Hardware and software components are described, as well as survey procedures, database design, and examples of typical SQL queries.

RÉSUMÉ

Strong, M. B., and P. Lawton. 2004. URCHIN – Manually-deployed geo-referenced video system for **U**nderwater **R**econnaissance and **C**oastal **H**abitat **In**ventory. Can. Tech. Rep. Fish. Aquat. Sci. 2553: iv + 28 p.

Le système vidéo "URCHIN" a été conçu en 1997, pour surveiller une profondeur maximale de 50 mètres et pour améliorer les méthodes de surveillance par plongée "SCUBA" qui décrivent les habitats benthiques côtières. Les produits d'information requit inclus; une vidéo de haute qualité géo-référencée (avec des données positionnelle superposée sur la vidéo), des logicielles géo-référencées pour la classification des habitats benthiques, l'enregistrement des rencontres biote et des données de profondeur et de température. Les attributs fonctionnels pour la vidéo sous marine sont; une camera et monture léger et robuste permettant un déploiement manuelle, une vitesse sur le fond de 1 nœud, et être fonctionnel dans très peu de lumière et sur des fonds turbides. Les attributs fonctionnels pour le système de surveillance a la surface sont; un système d'information géographique en interface avec un système d'observation et de navigation, une capacité d'annotation et d'enregistrement vidéo, le tout assemblé dans un montage indépendant et facile a transporter sur des bateau d'opportunité. Subséquemment, deux systèmes vidéo "URCHIN" furent assemblés et après application sur le terrain, un protocole de surveillance formel a été initiée en 2001. Les données de surveillance vidéo sont conservées dans une base de données relationnelle (base sur ORACLE) et des programmes SQL a été écrits pour une variété d'extraction de données. Les parties constituantes du "hardware" et du "software" sont décrites, ainsi que les procédures de surveillance, la description de la base de donnée et des exemples des programmes typique SQL.

INTRODUCTION

DEVELOPMENT OF REMOTE VIDEO SYSTEM APPLICATIONS

URCHIN is the third stage in the evolution of the Gulf of Maine Crustacean Fisheries Section's (GMCFS; Maritimes Region Science Branch) remote video system. The first stage was developed prior to 1997, when GMCFS performed *ad hoc* remote video monitoring of coastal benthic habitats using a custom-designed survey system based on an Amphibico Amphibian Probe camera (comprising a CCD image sensor and RGB color processor). This camera, which was mounted on a tripod equipped with a floodlight, could be manually deployed and operated using either 12V DC or 115 AC (see Appendix 1 for description and schematics). This system lacked positioning capability and sensors for temperature and depth recording. Also, the use of a floodlight to receive true color imagery caused back-scatter problems when used in the turbid waters of the Bay of Fundy. However, this system was used effectively to monitor lobster and sea cucumber distribution and behaviour (Lawton, unpublished data; Singh et al. 1999).

The second stage of development occurred between 1997 and 2001. A major field investigation of the distribution and abundance of juvenile lobsters in relation to coastal landscape features was undertaken as part of the Canadian Lobster Atlantic-wide Studies (CLAWS) program funded through DFO's Strategic Science Fund. As described by Rangeley and Lawton (2001) there was a requirement for a remote video system capable of providing geo-referenced video for ground-truthing seabed acoustic imagery obtained over relatively large areas (1–10 km^2 mapping regions) of inshore lobster habitat. The new video system developed under the CLAWS project employed a Kongsberg-Simrad OE 1393 monochrome CCD camera that had high resolution (525 lines @ 60 hz), and which could operate in extremely low light conditions (0.02 lux). Consequently, the system did not require a floodlight for working depths of up to 30 m. Survey depth was recorded by mounting a dive computer in the camera field of view. The camera mounting frame was a tripod design with a rudder mounted at one end to direct the camera into the current when performing drift transects. This system used portable differential geographic positioning (dGPS) equipment and an Outland Technologies video overlay unit to record National Marine Electronics Association (NMEA) data on the video image. Tracking of survey transects and logging of NMEA data was accomplished using the Microsoft-DOS-based AGCNAV software, provided by the Geological Survey of Canada (McKeown and Heffler 1997) which resided on a full-sized PC. Recording of video footage employed a SONY video camcorder recording on Hi-8 mm analog videotapes. The system was used successfully between 1997 and 1999 on larger DFO research vessels such as the "Opilio" and the "J.L. Hart" that could accommodate the volume of equipment required.

This second system had three deficiencies. The primary problem was the lack of an expedient means of logging annotation and positional data for biota and bottom type to separate data files. The second deficiency was the lack of a clean electrical power source suitable for sensitive electronics that could operate independently from the survey platform. The third shortcoming was that the system was much too large for use on smaller vessels of opportunity.

URCHIN SYSTEM SPECIFICATIONS

The current videosystem (Appendix 2) has been named **URCHIN** (**U**nderwater **R**econnaissance and **C**oastal **H**abitat **In**ventory) to reflect its general application for coastal ecosystem research, and in recognition of its affordability and humble beginnings (*sensu* street urchin). The URCHIN system adopts the same tripod rudder frame design, and uses a similar high resolution low light Kongsberg-Simrad OE1359 camera (525 lines @ 60 hz and light sensitivity of 0.03 lux). An optional 250-watt floodlight can be utilized in very dark conditions.

Temperature and depth data are captured during every cast using a Vemco Minilog temperature and depth recording unit that is attached to the mounting frame and downloaded daily.

As a means of regulating the aspect of the tripod camera frame, and thus the camera "footprint", a visual cue is provided for the camera operator using underwater lasers. Two battery-operated underwater laser pencils are parallel mounted on the frame aiming forward and downward, so that laser dots reflected off the substrate appear within the center of view when the camera is being "flown" correctly. Disappearance of the dots in the foreground or over the horizon will prompt the operator to retrieve or pay out cable respectively to restore the optimal camera footprint.

Field survey planning, vessel navigation, transect mapping and survey data management are performed with a Panasonic Toughbook CF-27 ruggedized notebook computer using Mapinfo geographic information system (GIS) software. The use of the Geotracker tool within Mapinfo allows for NMEA position data logging, and survey tracks can be saved as polyline objects for future display. An interactive, Windows-compliant, geo-referenced annotation software (Class-Event) has been developed in-house for logging survey start and end-points, and simultaneous logging of bottom type (classes) and biota encounters (events). Class and event annotation can be accomplished either through the computer keyboard, mouse, or a remote keypad, and there is flexibility for user-defined data codes. For UTC (Universal Time Conversion) data and positional data, the NMEA data accessed by Class-Event software originates from the $GPGGA data sentence.

A portable dGPS unit (Garmin GPSMap 162 with GBR23 differential receiver) is used for the collection of positional data independent of the survey vessel's navigation system, and is interfaced with an Outland Technologies video overlay unit to overlay time and positional data on video as it is recorded. Video recording is accomplished with a Sony GV-D900 mini-DV format video recording unit. This component has an integrated 5.5 in. LCD screen which is used by the survey operator conducting survey annotation tasks. Typically, an additional TV monitor is set up to provide accessible viewing for the camera operator.

A Honda 1000E portable generator is used as an independent and compact source of clean AC power. All components of the system are contained on a wheeled two-shelf cart which can be lifted or wheeled aboard small vessels with ease.

SURVEY APPLICATIONS

Since the initial redesign in 1997, the URCHIN video system has been used by a range of researchers including Peter Lawton for benthic ecology and fisheries surveys (Lawton et al. 2001), other DFO researchers (Robert Miller and John Tremblay) from the Bedford Institute of Oceanography (BIO), Russell Parrott from Natural Resources Canada (BIO) for geological surveys (Parrott and Strong 2003), and John Hughes-Clarke of the Ocean Mapping Group, University of New Brunswick, Fredericton, N.B., for ground-truthing of seabed acoustic imagery. The current and anticipated uses of the system are summarized below:

1. **Stock Assessment:** The primary stock assessment-related objective of the remote camera surveys conducted by the GMCFS has been to determine the distribution and abundance of lobsters, crabs and sea urchins, and to record the associated biota and habitat.
2. **Ecological Research:** For more rigorous ecological analyses of community structure, the recorded video from URCHIN system surveys can be archived for subsequent laboratory-based post-processing for detailed determination of species assemblages.
3. **Interpretation of Acoustic Imagery:** The requirement for comprehensive seabed mapping of inshore areas is growing. The URCHIN system has proven to be extremely valuable in ground-truthing side-scan sonar and multi-beam sonar acoustic mosaics of the seabed, in terms of providing geo-referenced images for interpreting how different bottom conditions produce different patterns of back-scatter.
4. **Baseline and Impact Surveys:** Coastal aquaculture site development and marine industry infrastructure improvements (wharf construction, harbour dredging and spoil disposal) are often done on short notice, without adequate baseline information about the ecology of the areas to be impacted. Pre-development video surveys with the URCHIN system can provide geo-referenced baseline video observations, and can be accomplished in an expedient fashion using vessels of opportunity. Follow-up surveys can then be performed against which subsequent changes in habitat conditions can be documented.

FIELD OPERATIONS GUIDE

Typically, two scientists are required to operate the URCHIN system, one to manually "fly" the camera, and one to operate the GIS software and video recorder, perform data logging, and manage files. These roles are swapped on a regular basis as manual deployment can be very tiring work.

Pre-survey preparations normally include delineating "target areas" in the GIS survey workspace of a size that can be surveyed on video without changing recording tapes (typically, 60 min recording length). Target areas are normally set at less than 500 m in dimension, as at a speed of 0.5 knots, about 463 m is traversed in 30 min allowing two transects to be recorded per tape. Waypoints of the target areas are often entered into the vessel dGPS units to assist the captain in navigation, and the vessel tracking is displayed relative to the target transect using the GIS throughout each cast. In the event of strong tidal action or wind, the direction of target transects is altered to facilitate camera deployment over the target area. Small vessels of less than 400 HP

have proven the best at maintaining course and the optimum speed over ground of 0.3-0.5 knots. Ideally, the camera is not towed over the bottom. In lieu of towing the gear, a "corrected drift" is conducted by periodically clutching the vessel's engine in and out, successively altering the course to follow the target transect. If the "corrected drift" can be achieved without excessive powering by the vessel, the position of the camera can be maintained directly below the dGPS receiver antennae (mounted above the snatch block used for cable deployment), and thus dGPS positioning error is minimized.

The correct means of "flying" the camera is achieved by maintaining the tripod so that the rear legs are just touching the substrate, with the foreleg slightly elevated. When the camera aspect is correct, twin laser dots (from lasers mounted and calibrated prior to deployment) appear in the central field of view as a guide for the operator.

Further details of the URCHIN system hardware setup are found in Appendix 2. General details of software usage, camera deployment, and file management are found in Appendix 3.

INTERACTIVE ANNOTATION USING CLASS-EVENT SOFTWARE

The Class-Event software was developed within DFO to enable researchers to interactively log "events" such as sightings of various biota, and "classes" which are user-defined categories of seabed or habitat type. This approach is analogous to, and was modeled after, behavioral event recording approaches, with the difference that the observations are recorded along with the geographic position, in addition to the time at which they occur. Class and event data are independently logged to separate data files along with their associated NMEA data. Once a "class" definition has been entered (such as when a defined habitat type first appears on the video screen) that definition is subsequently logged automatically by the software at each NMEA update (2 or 3 s intervals) until another habitat class is defined by the operator. This provides for the quasi-continuous geo-referencing of habitat type. For user-defined "events", the event, geographic position and time are logged when the user enters the event code. Further details of software usage are provided in Appendix 4.

The key data element used to join class and event records to temperature and depth data, and to the corresponding video footage is time. It is very important to ensure that the time sources are synchronous, and that the necessary conversions are done to correct for time zone so that datasets will match. For the URCHIN system, the standard is GMT (Greenwich Mean Time, also known as Universal Time Conversion or UTC). The time logged by the Class-Event software is acquired directly from the NMEA data as GMT in the 24-h clock format (hh:mm:ss). The time stamp overlaid on video footage is also derived directly from NMEA stream GMT values, and so will match the Class-Event logged values depending on the choice of format displayed by the overlay computer (hh:mm:ss). However, the time stamp logged by Vemco data loggers for temperature and depth is derived from the system settings of the host logging computer in local time, and care must be taken to check that the minute and second settings match the GMT values displayed on the NMEA data stream prior to data collection. This can be done expediently by running Class-Event software with live GPS input and comparing the times displayed to the logging computer's system date and time properties. The times should agree within a few seconds (hours will be offset by either 3 or 4 h depending on local time in the Maritime

Provinces of Canada). As our computer system time settings are updated from GMT and converted to local time each time a system is logged on to the DFO network, system times should agree closely with GMT. Any offsets would be due to lag or gain of the computer clock incurred since the last network login.

Prior to loading to the database, time fields undergo an additional conversion to a numeric data type so that queries to extract information such as elapsed time can be done efficiently. See Appendix 5 for data conversion protocols; Appendix 6 for examples of time calculations using numeric fields.

ORACLE DATABASE DESIGN

The URCHIN relational database was designed to attempt some degree of normalization to avoid the redundant storage of information, yet to be comprehensive enough to facilitate making simple queries to extract summaries of all field data collected. With the use of only two primary keys (for consecutive set number and timestamp) in the URCHIN database, datasets for depth and temperature can be easily merged with geo-referenced observations of substrate and biota, although these were logged independently. It is imperative when constructing a database to have some notion of what extractions you will likely attempt, and design the tables accordingly. Although our choice of using a numeric data type for time gave us some latitude in constructing our own time functions and facilitating table joins, the option of loading these data as time and date data types would allow for the use of generic SQL date and time functions if so desired.

The database was designed with 3 tables named Remoteinf, Remotetdr and Remotecsv, and are joined by the primary keys for set number and time stamp. Remoteinf is a general information table giving details of each set such as set number, date, time, location, operator and video storage location. The Remotecsv table houses detailed information about each set, including location code, and the position, substrate and biota observations logged by the Class-Event software. The Remotetdr table houses details of time, depth and temperature as logged by a "Vemco" minilog time depth recorder during each set. Details of post survey data transformation, table descriptions, and loading procedures to Oracle are described in Appendix 5.

DATABASE QUERIES

In order to extract data summaries, the Remotetdr and Remotecsv tables are joined by the set number and numeric time stamp, and binned by minute, as the "seconds" portion of the time stamp seldom matches in both tables. In order to calculate set duration, timestamps are converted to elapsed minutes per day within a given query. Typical queries include extracting summaries of a given observation by selected location, depth, temperature and time. Example queries are included in Appendix 6.

AN EXAMPLE TRANSECT

To illustrate the use of the URCHIN system, Appendix 7 presents several aspects of the survey information captured from a video transect performed to survey lobster distribution, and ground-truth a multi-beam sonar mosaic in Flagg Cove, Grand Manan. A representative frame from the

video imagery, extracted data from the Oracle database, and GIS software screen captures from the Mapinfo workspace for Set 23 (obtained on September 4, 2002) is included in Appendix 7.

DISCUSSION

The primary virtues of the current version of the URCHIN system are compact size and transportability for use on small vessels of opportunity. The camera package is light weight and can be hand deployed to depths of 50 m eliminating the need for winches. The camera returns high resolution imagery in low light conditions eliminating the need for flood lights in most survey conditions. The system is extremely robust, and has been frequently used over rocky and kelp covered bottom without loss or damage to the components. The camera cage design is surprisingly resistant to catching down, and reversing the vessel course usually succeeds in freeing the unit. As the system is normally used in shoal conditions, retrieval using a diver is likely to be a feasible option if the system has to be left on the bottom.

The system is self-contained and uses independent power supply and navigation hardware eliminating dependence on host vessel equipment (which varies greatly in makes, quality, connectivity and state of repair). The system is relatively inexpensive and delivers a similar product to other systems that require large platforms, winches, telemetry, and complex operating systems to deploy. As all components are purchased commercially, maintenance of the URCHIN system does not require an in-house engineer for repairs. They can be serviced directly by manufacturers, or replaced with spare components when performing a survey. The system is very easy to hook up and operate, and users can be trained in a matter of hours to set up the hardware and use the software employed. Although the system can easily be operated by a novice user, there is a clear requirement for operator experience and prior training in understanding the set of observation criteria to be used in any specific survey application.

Positional and annotation data are currently logged using Class-Event software, and time and position are simultaneously captured by overlaying the data directly on the video. The overlaid data provides geo-referenced labels for the video for post processing if required, but also provides excellent back-up protection in the event that the associated logging files are lost. The current version of the Class-Event software is flexible in allowing different users to elect distinct keyboard assignments for specified annotation events. Suites of keyboard assignments can be tailored for each type of survey and then saved in distinct configuration files (.ini files). The appropriate configuration file can then be loaded into the software prior to the survey.

Our adoption of Class-Event software was undertaken in an attempt to reduce the amount of post-processing of survey video footage. However, there are obvious limitations to the complexity and accuracy of real-time field annotation of habitat and biota variables. As the survey proceeds in real-time, it is difficult for the software operator to properly gauge when a transition has occurred between broad habitat categories, such as from a mud-dominated bottom to a sand and gravel bottom. Frequently, the video transects a relatively small patch of the new habitat type within a larger habitat region. Similarly, the system operator can only keep track of a relatively small number of biota variables in real time to ensure that accurate recording is maintained. These limitations led us to adopt relatively broad habitat descriptors and a few principal biota variables for field recording, and to accept that post-processing of video would

still be required for complete analysis. Nonetheless, the Class-Event software can provide a very important capability for rapid survey assessment in the field and thus, an opportunity to utilize adaptive survey designs where specific habitat and biota variables in a specific location can trigger additional video surveys.

One possible improvement that might be made to Class-Event software would be to add the flexibility of being able to choose the NMEA data for logging as was possible with AGCNAV software. The current default is for UTC or Universal Time Conversion data and positional data from the $GPGGA data sentence. Such data might include GPS quality indicators and horizontal dilution of position from $GPGGA, and speed over ground from $GPVTG.

There are several other system enhancements which would increase the range of survey applications, yield more quantitative data on biota and habitat structure, and further ensure the archival value of the acquired video.

A limitation of the Kongsberg Simrad OE 1359 camera used by the current URCHIN system is the fixed focal length of the camera itself, and the restricted field of view afforded from the mounted position on the frame (downward and forward orientation). When conducting a survey, it is possible for objects to escape the camera footprint before accurate observations and annotation can be accomplished. Also, areas to each side of the survey transect are out of view, and may represent very different habitat types from those being surveyed. Acquisition of such information would be useful in understanding the distribution of biota observed along a survey transect. Although the first problem can usually be remedied by post-processing the video, resolving the second problem would require enhanced control over the orientation of the camera itself and the acquisition of zoom capability. Future developments of the system are thus anticipated to involve the mounting of a zoom camera lens with 360-degree pan, and 90-degree tilt capabilities.

Presently, the selection of a video sequence for laboratory post-processing is accomplished by performing an Oracle query with the desired selection criteria, locating the correct tape, and then advancing it to the correct time stamp on the video. Ideally, if NMEA and annotation data were captured and encrypted directly with the video signal and stored digitally, it would be possible to query sequences directly for immediate relational database access. The availability of such technology is being investigated for future development of marine video data management within DFO (Clement 2003). However, the disc storage requirements for all imagery to reside digitally would currently be prohibitive.

As an interim development, a capability to store NMEA data on the physical video medium and to then replay this data through to the Class-Event software as the video is played back during video-analysis would facilitate expansion of the software to a comprehensive analysis suite.

Due to the lowering costs of capturing high quality video imagery, use of video in marine fieldwork has increased dramatically in the last two decades, and current applications can be sophisticated and extensive (e.g. Smith et al. 2003; Stokesbury et al. 2004). Associated with this trend has been a proliferation in the volume of captured imagery held by marine science organizations, including DFO, in various formats. Recent concern has been expressed regarding

the stability and security of the various video storage media used within DFO (Clement 2003), as the loss of quality with time has been demonstrated with older VHS format tapes. Historically, our practice within GMCFS has been to use analog Hi-8 tapes for video capture and storage. Our present method is to use min-DV digital tapes as an initial capture and storage medium, and to then transfer imagery to DVD discs for longer term storage.

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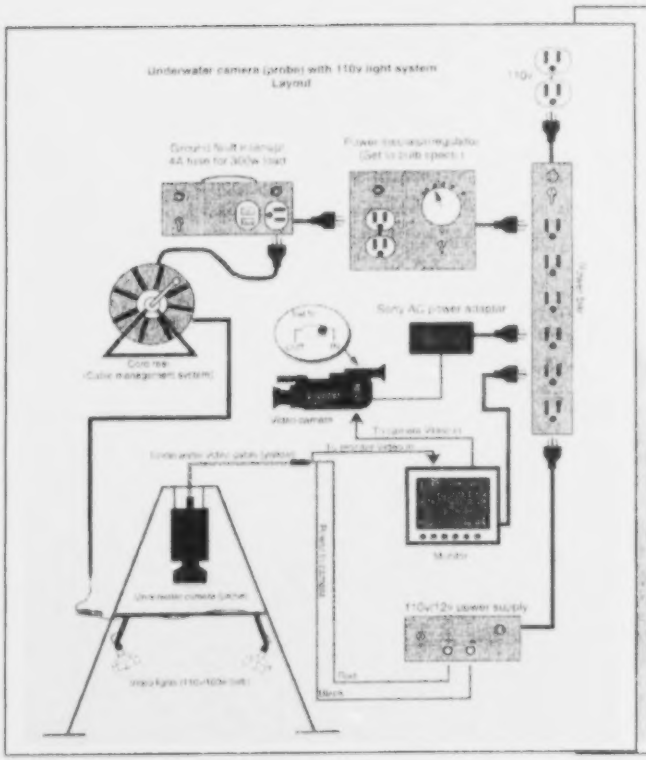
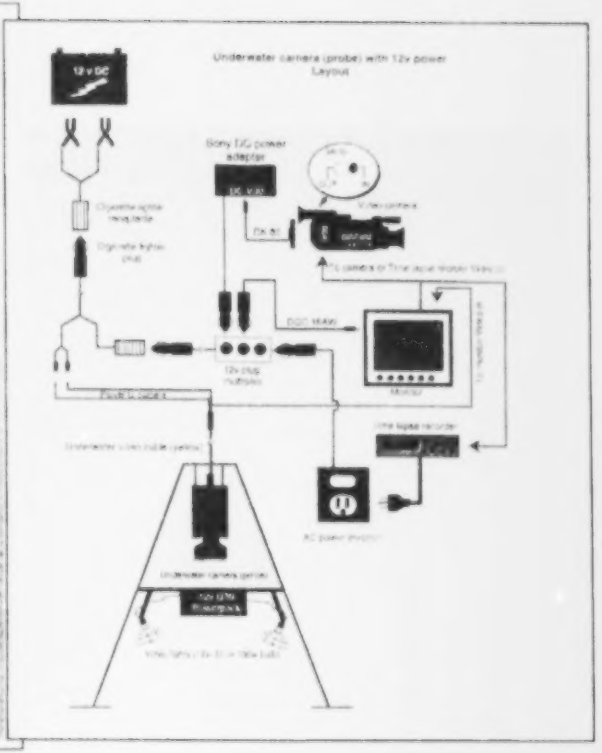
Stokesbury, K.D.E., Harris, B.P., Marino II, M.C., and Nogueira, J.I. 2004. Estimation of sea scallop abundance using a video survey in off-shore waters. J. Shellfish. Res. 23: 33-40.

APPENDIX 1. AMPHIBICO SYSTEM USED PRIOR TO 1997

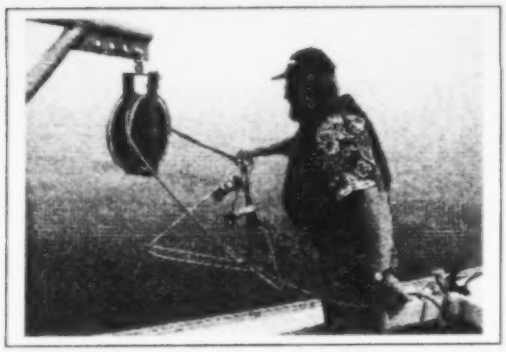




AC Voltage Setup

DC Voltage Setup

APPENDIX 2. URCHIN SYSTEM HARDWARE COMPONENTS AND SOFTWARE



System being deployed off vessel

dGPS receiver, monitor, laptop, and mini-DV deck

1. Kongsberg-Simrad OE1359 camera with DQ250 light and 100 m of cable
2. Stainless steel cage for camera deployment
3. Kongsberg-Simrad Power supply model OE1232
4. Underwater lasers for scaling camera footprint
5. Outland Technology Model 5000A video overlay and power supply
6. Panasonic Toughbook CF-27 computer with port replicator model CF-VEB272A
7. Garmin GPSmap 162 receiver and antenna
8. GBR 23 differential receiver
9. Techcessories regulated 12 volt power supply for Garmin GPS
10. Honda 1000 watt Whisper model "E" generator with fuel container
11. Ground Fault extension cord 5 m (User Supplied)
12. Surgemaster II power bar
13. Two-shelf mobile cart for housing and transporting hardware components
14. Video monitor (User Supplied)
15. 12" stainless steel snatch block (User Supplied)
16. Vemco temperature and depth recorder (TDR minilog) and computer interface (User Supplied)
17. Power/data cable for Garmin 162 GPS data uploads and downloads
18. Digital video recorder and tapes as required (User Supplied)
19. Laser alignment template
20. Geographic information system software (Mapinfo version 6.0)
21. Electronic marine charts as required (User Supplied)
22. Mapsource software for uploading waypoints to GPSmap 162
23. Geotracker software for NMEA data logging (software tool within Mapinfo)
24. Class-Event software for geo-referenced habitat and biota data logging
25. Vemco software for temperature/depth data logging and downloading
26. MS Access software for logging survey activity
27. Additional software tools as required (e.g. Mapinfo bearing tool for directing vessel)

APPENDIX 3. URCHIN SURVEY OPERATION PROTOCOLS

INITIAL HARDWARE CONNECTIONS

1. Connect groundfault extension cord to Honda 1000 generator
2. Connect Power bar to extension cord
3. Connect Toughbook to port replicator dock
4. Connect external mouse to Toughbook port replicator dock
5. Connect external keypad to Toughbook port replicator dock
6. Connect both 9-pin connectors from GPS wiring harness to com ports 1 and 2 cn Toughbook port replicator dock
7. Connect Toughbook port replicator dock, video overlay transformer, GPS 12 volt power supply, Kongsberg-Simrad camera power supply, Sony monitor, and DVD recorder power cords to power bar
8. Connect orange camera power cable to camera power supply
9. Connect video out from camera power supply to video in on video overlay
10. Video out connections from video overlay to video in on monitors and recording decks will vary with user supplied equipment
11. Connect RS-232 from GPS wiring harness to video overlay computer
12. Install dGPS receiver and GPS antennae directly above snatch block and connect to GPS wiring harness

START OF DAY OPERATIONS

1. Fuel, check oil and start the generator
2. Reset the ground-fault breaker on extension cord
3. Turn on the power bar
4. Turn on the camera, video overlay, video monitor and digital video recorder
5. Calibrate the lasers using the deck template to display two laser dots at 25 cm apart below the field of view so that these points are visible when flying the camera
6. Turn on GPS system and set communications to NMEA in/NMEA out and check for 3d differential reception using NMEA 0183 Version 2.0
7. Reset video overlay and test for correct NMEA string
8. Boot the computer
9. Initiate a Mapinfo session
10. Open the appropriate chart table or workspace
11. Open tables containing the target transects
12. Initiate Geotracker and use polyline to track position
13. Initialize Vemco TDR using reader and secure to camera cage for multiple deployments (one file generated daily and saved to c:\surveys\data directory).

INITIATION OF A SET: DECK SHEET AND PROCEDURES

1. Write survey number, transect number, date, location and camera operator on a deck sheet, set card within the camera view, ensure it is legible on the video screen, then record briefly.
2. Initiate Class-Event software, and elect a habitat logging file name and a biota logging file name. These files should be saved in the c:\surveys\data directory. File naming convention should be as follows: a two character location identifier, date formatted as "ddmonyy", "h" for a habitat file or "e" for an event file, and a 3 digit transect number. These files are assigned .csv extensions by default. For example, the habitat and event files for Lobster Bay October 15 transect 12 would be LB15oct01h012.csv and LB15oct01e012.csv.
3. Using Geotracker, modify the polyline in the "set up tracking" menu to mark the track of a new set by changing the colour of the line.
4. Initiate video recording.

DEPLOYMENT OPERATIONS

1. Deploy the camera before the start of the target transect, employing the snatch block to avoid disturbing the laser settings
2. Fly the camera at speeds between 0.3 and 0.7 knots if possible, and maintain the 25 cm laser dots within the window enclosed by the forefoot of the camera cage and the lower field of view.
3. Log start set, end set, habitat type and biota events as indicated on the keyboard map. For a detailed summary of logging protocols, see Class-Event Logging Protocols (Appendix 4).

END OF SET OPERATIONS

1. Using Class-Event software, log end of set prior to camera retrieval from bottom, and end Class-Event logging.
2. Retrieve the camera and turn off light before removal from water.
3. Terminate video recording, remove and label tape with date, survey and set information.
4. Use video recording log to record tape and transect information.
5. Save the two Class-Event.csv files to the C:\surveys\data directory by ending the logging upon retrieval of the camera on deck.
6. Open c:\Program Files\Mapinfo\professional\gps\gpstemp.tab and save polyline table of the set track by saving as Survey/Set.tab in the c:\surveys\data directory (LB15oct01012.tab).

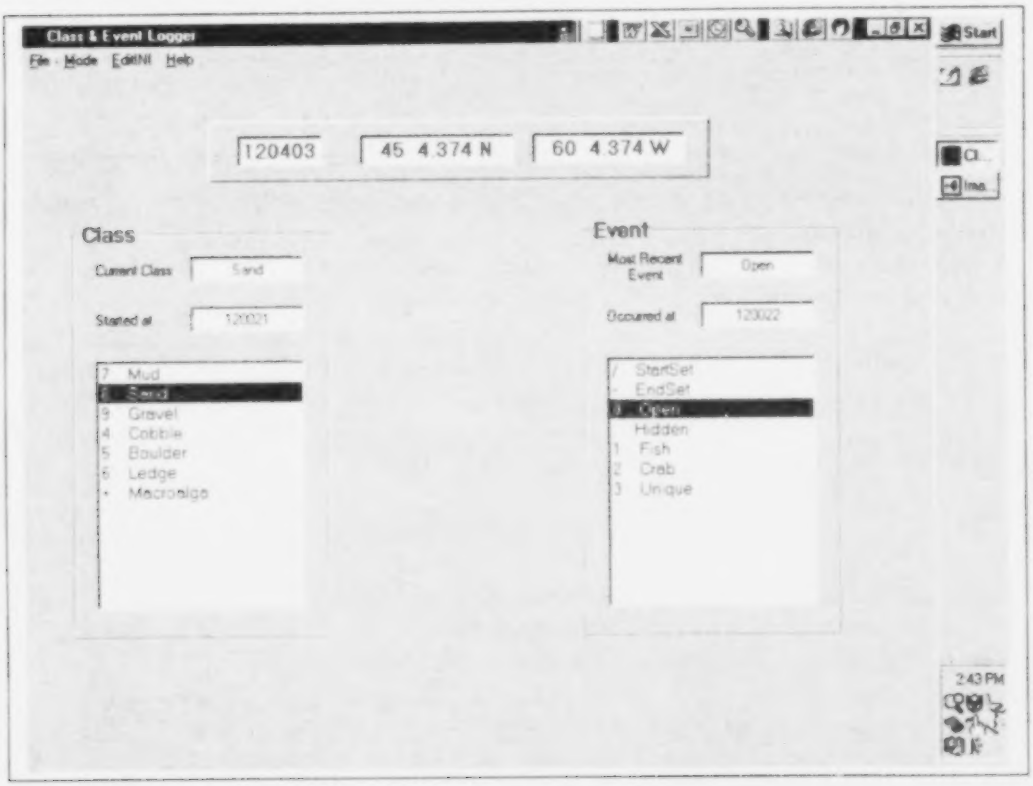
END OF DAY OPERATIONS

1. Save Vemco TDR minilog file for the day's casts, and save to c:\surveys\data directory.
2. Log survey activity in Access database.
3. Save all Mapinfo transect tables to a workspace dedicated for survey.
4. Log off computer and turn off camera, GPS, camcorder and generator.
5. Secure gear for next day's operations.
6. Back up Class-Event files on floppy discs for day's operations.

APPENDIX 4. CLASS-EVENT SOFTWARE AND LOGGING PROTOCOLS

Class-Event Software Overview:

The main window for Class-Event logging software appears as below. In this case, input of NMEA data has been identified by the appropriate COM port, two files have been named for the logging of class and event data, and the class and event variables have currently been elected as "sand" and "open" respectively. It is essential that this software be the active window to enable logging to be accomplished, if multiple programs have been opened in the operating system.



Class-Event Software Details:

The following description of Class-Event software was extracted directly from the 2002 version of the program, authored for the Department of Fisheries and Oceans by Dr. D.L. McKeown at the Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada.

This program is used to create comma delimited (CSV) data files of time and position stamped bottom classification descriptions and discrete events while observing underwater video, seismic records, etc. in real-time. It could also be used in a playback mode if the video or seismic replay system is capable of generating NMEA0183 $GPGGA serial data strings synchronized to the

displayed information. The computer must be connected to a source of NMEA0183 position information containing a $GPGGA string in order to create these data files

The program starts up in the On-Line mode with data logging turned on and the current position derived from the incoming $GPGGA string plus the Class and Event lists defined by the user are displayed. There are separate lists for Class and Event. Each description in each list is preceded by a unique hot key. An occurrence of a Class or Event is identified by either pressing the corresponding hot key or left clicking on the desired selection with the mouse. When either a Class or Event is selected, it appears in the window above its list along with the time of selection. The lists of bottom classifications and discrete events are contained within the text file CLASEVNT.INI. These lists can be altered by clicking on the menu EditINI.

Data logging is initiated by clicking on the Files menu then selecting either New to create new Class and Event data files or Append to log data to existing files. These data files are closed when the Mode or CLASEVNT.INI file are changed, the program is closed or the user selects menu path File/Close All. Whenever the data logging files are closed, the warning message "Not Logging Data" appears on the screen.
Two data files, a "Class" data file and an "Event" data file are created when data logging is activated. Both are comma delimited (CSV) text files with fields: Date, Time, Lat, Long, and Class or Event. Because the Date field is derived from the logging computer whereas the Time field is derived from the incoming $GPGGA string, the computer clock should be set to GMT to make the two correspond correctly near midnight. The position is recorded in decimal degree format to make it readily compatible with GIS software. Whenever the selected Class is anything other than "None", a record will be written to the Class file every time the position information is updated via an NMEA0183 $GPGGA string. The "None" classification can be recorded in the Class file, by changing its description to anything else, e.g., "Nonex". A record is written to the Event data file only when one of the event hot keys is pressed or when the cursor is moved to the appropriate line on the event list and the left mouse button clicked.

Sample Class file:

18/07/01,180036,44.640117,-63.618633,S,Sand
18/07/01,180038,44.640117,-63.618633,S,Sand
18/07/01,180040,44.640117,-63.618633,S,Sand
18/07/01,180042,44.640117,-63.618633,S,Sand

Sample Event file:

18/07/01,180044,44.640117,-63.618633,F,Fish
18/07/01,180048,44.640117,-63.618633,L,Lobster
18/07/01,180050,44.640117,-63.618633,C,Crab
18/07/01,180054,44.640117,-63.618633,O,Other

In addition to the On-Line mode, the program can be run in the Demo mode which does not require serial data input. All incoming serial data can be viewed when the ViewCOMport mode is selected.

Gulf of Maine Crustacean Fisheries Section Class-Event data logging protocols:

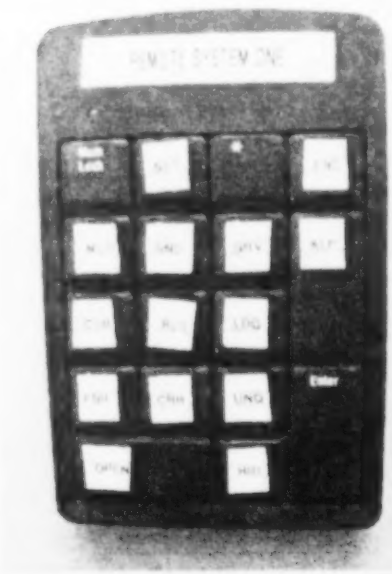
The following description of Class-Event data logging protocols demonstrate the application of the software to the survey of coastal invertebrate populations, primarily lobster, and the preliminary ground-truthing of acoustic seabed imagery. These protocols were used by the Gulf of Maine Crustacean Fisheries Section in surveys conducted between 2000 and 2003. These are not meant to constitute a generic habitat and event classification scheme, but are reported here to provide a reference to that initial period of coastal habitat survey.

External Numeric Keypad designations for data entry:

A numeric keypad (Fig. 4) was labeled to facilitate recording of habitat (Class) and biota (Event) data without the requirement to use the computer mouse, permitting the observer to maintain attention on the video display, rather than having to coordinate actions between the computer and video display. The layout of the labels was designed with consideration for the ergonomics of the specific biological survey objectives; thus the general set descriptors are arrayed at the top of the keypad, habitat classes are grouped together in the central portion of the keypad, with the event codes below. Prior training in habitat categorization and species identification is recommended before rapid survey annotation such as that described below is required of field survey personnel.

KEY	LABEL	DESCRIPTION
/	SET	Start Set
-	END	End Set
	Habitat Classes	
7	MUD	Mud
8	SND	Sand
9	GRV	Gravel
4	COB	Cobble
5	BLD	Boulder
6	LDG	Ledge
+	KLP	Kelp
	Event Codes	
1	FSH	Fish species
2	CRB	Crab species
3	UNQ	Unique event
0	OPEN	Lobster in the open
.	HID	Lobster in burrow

Fig. 4: Keypad Overlays



The protocol for GMCFS survey sets includes "landing" the tripod after each habitat transition and at intervals within each habitat to obtain close-up footage for post-processing of habitat structure. A brief period with the tripod at rest on the bottom will help separate mud, sand, and gravel-dominated bottom. When the tripod grounds due to changes in height over bottom, do not immediately pull the tripod off the bottom (unless there is a danger of getting the tripod hung up on a bottom feature). Designation of transitions in real time can be difficult as the bottom type that lies ahead is unknown. Designation of a new bottom type should only be made after it is verified with adequate footage. Try to avoid keying many changes in CLASS designation, as for example when going over isolated boulder patch on soft bottom (e.g. patch of 2-3 boulders).

EVENT (SURVEY SET) DESIGNATIONS

The assigned keys on the top row of the keypad are reserved for the survey set locations:

SET– Press this key when the camera first comes to rest on the bottom at start of survey set.

END – Press this key at the end of the survey set before the camera is raised from the bottom.

HABITAT (CLASS) DESIGNATIONS

MUD-Mud bottom: A mixture of silt and clay-sized particles (following the Wentworth scale). This substrate does not usually having any macroalgal cover, but may have sparse algal patches where larger material (cobble boulder) is embedded. Mud bottom may have considerable bioturbation, such as excavated holes and depressions. The tripod legs may settle in mud, and can often provide an indication of the compaction of the sediment. There may also be some structure on bottom due to the accumulation of bivalve shells into low reef features.

SND-Sand bottom: The bottom may be relatively flat. In shallow depths where wave action is significant, or in deeper locations where currents are strong, sand bedforms such as ripples and megaripples may be developed. It is common to have mixtures of coarser material (gravel, cobbles, etc), either dispersed within the sand, or present as specific microhabitat features.

GRV-Gravel bottom: In the Wentworth classification, gravel is represented by particles larger than 4 mm in diameter, and is divided into gravel, pebble, cobble, and boulder categories. However, for the purposes of the GMCFS surveys, the gravel bottom designation was used where the predominant particles were small, less than 6.4 cm in diameter. Operationally, gravel would be designated where most particles forming the bottom were clearly less than 10cm diameter (e.g. falling within the two central bars on the frame when tripod is grounded). Under this description, this bottom type may form a transitional habitat between mud or sand bottom at greater depth and cobble and boulder fields adjacent to shore. Gravel beds may occur on a variety of base substrates including mud and sand, as well as accumulations of gravel into uniform beds. Gravel does not usually have extensive kelp cover, but may have isolated algae patches where larger particles (boulders) or ledge (bedrock) occurs in the habitat.

COB-Cobble: In geological terms, cobble is part of the gravel size classification, but they are of specific significance for describing coastal lobster habitats, as they form a preferred habitat for

lobster settlement and early benthic growth. Round or irregular shaped particles ranging from 6.4 to 25.6 cm in diameter, cobble is operationally designated where most particles observed on the screen cover 25 – 100% of the distance between the 25cm laser scales. Cobble is also designated where boulders or rock ledges are infrequent to common, but do not form over 50% of the bottom area.

BLD-Boulder: This bottom has most particles exceeding 25.6 cm in diameter. Operationally, most particles exceed the 25cm laser scales. Boulder fields will commonly occur with ledge outcroppings, patches of sand, and/or cobbles, but these features will commonly cover less than 50% of the field of view. BLD is designated where the habitat does not have extensive kelp or other macroalgal cover.

LDG-Outcropping of underlying bedrock: Ledge used to designate habitats that range from horizontal platforms of bedrock through various degrees of slope to vertical rock walls, which may or may not be extensively fissured. We do not differentiate between horizontal and vertical relief features. Ledge is identified with areas that do not have an extensive kelp canopy.

ALG-Primarily kelp beds: This habitat description is used where kelp (macroalgae) is a dominant feature of the habitat, forming a more or less complete canopy over the bottom. This habitat description is also used to designate other algal beds such as rock weed and eelgrass where the canopy is too thick to see the feature below. Where algal habitats other than kelp are designated, a note should be made in the survey documentation as to the species forming the canopy.

EVENT (BIOTA) DESIGNATIONS

OPEN – When encountered in the field of view of the camera the lobster is either seen moving actively across the sea bottom, or if it appears to be stationary, is not clearly associated with any shelter (e.g. may be in process of feeding in the open).

HID – When encountered by the camera the lobster is clearly associated with a shelter. Shelter can include objects such as rock outcrops, boulders, cobbles, algal cover, ghost traps, weir stakes etc. When disturbed, the lobster may respond by moving away from the shelter, but the key event designation is based on the initial encounter.

FSH – Encounter with fish in field of view of camera. No attempt should be made in real time tracking to classify to species, as attention diverted to this may result in missing an encounter with primary target (lobster). The event could be observation of one fish, several fish in close proximity, or a school of fish.

CRB – Encounters with crabs are to be logged, with no discrimination of the species in real time.

UNQ – A final event category is reserved for logging unique features on the sea bottom (ghost traps, sunken treasure) which may be of interest for subsequent review. When a unique feature is logged on a survey set, a comment should be made in the field notes for the set.

APPENDIX 5. POST-SURVEY DATA COLLATION, DATA LOADING AND ORACLE DATABASE TABLE DESCRIPTIONS

POST-SURVEY DATA COLLATION:

Prior to loading data into Oracle tables, the following re-coding and data transformations are required. The purpose for these data transformations is to enable joins between data tables using unique set numbers and matching time stamps (see Appendix 6).

1) Recoding of Class and Event observations:
Class-Event data that have been logged using the keys -,/,.,+, for EndSet, StartSet, Hidden, and Kelp are re-coded to (10,11,12,13) respectively. Also, class and event files are merged into a single file, and both fields are reported as a single variable named "Observation".

2) Conversion and transformation of time stamps:
The Class-Event data are logged using Greenwich Mean Time (GMT) on a 24-hour clock format (hh:mm:ss), and the TDR data (Time Depth Recorder) are logged using local time also in the same format. Therefore, the TDR times need to be converted to match GMT by adding 3 hours to times recorded in Daylight Savings Time, and 4 hours to times recorded in Atlantic Standard Time. As time stamps are maintained as numeric fields in the database, TDR times are converted to a number by adding 30,000 (3 hr, 0 min, 0 s) to achieve GMT time when recorded in Atlantic Daylight Time, and 40,000 (4 hr, 0 min, 0 s) to achieve GMT time when recorded in Atlantic Standard Time. Time captured as numeric data fields facilitates calculations of elapsed time for such queries as set duration.

3) Consecutive set number assignment:
As set numbers must be unique in the database (table constraint for primary key), new sets are re-assigned consecutive set numbers prior to loading.

DATA LOADS USING SQLLDR:

```
load data
into table remotecsv append
(location position(1:3) char,
rdate position(17:24) date "mm/dd/yy",
hhmiss position (27:32) integer external,
setno position(15:16) integer external,
lat position(33:40) integer external,
lon position(41:49) integer external,
key position(56:57) integer external,
observation position(58:68)char)
```

```
load data
into table remotetdr append
        (location position(1:3) char,
        rdate position(10:16) date "dd/mm/yy",
        hhmiss position(19:24) integer external,
        setno position(31:32) integer external,
        tempc position(36:40) integer external,
        depthm position(44:48) integer external)
```

ORACLE DATABASE TABLE DESCRIPTIONS:

REMOTEINF

Name	Type	Field Description
Name	Char(25)	Set location name
Setno	Number	Set Number
Starttime	Number	Time at start of set
Rdate	Date	Date for set
Startlat	Number	Latitude in decimal degrees at start of set
Startlon	Number	Longitude in decimal degrees at start of set
Operator	Char(25)	Name of camera operator
Vessel	Char(25)	Name of vessel
Tapenumber	Number	Tape number
Tapelocation	Char(25)	Location of tape
Startfootage	Number	Start footage for set number
Endfootage	Number	End footage for set number
Endtime	Number	Time at end of set
Endlat	Number	Latitude in decimal degrees at end of set
Endlon	Number	Longitude in decimal degrees at end of set
Remarks	Char(30)	General remarks for set

REMOTECSV

Name	Type	Field Description
Location	Char(3)	Set location name
Rdate	Number	Date for set
Hhmiss	Number	Time stamp
Setno	Number	Set number
Lat	Number	Latitude at time (hhmiss)
Lon	Number	Longitude at time (hhmiss)
Key	Number	Key code for observation
Observation	Char(20)	Observation

REMOTETDR

Name	Type	Field Description
Location	Char(3)	Set location name
Rdate	Date	Date for set
Hhmiss	Number	Time stamp
Setno	Number	Set number
Tempc	Number	Temperature in degrees Celcius
Depthm	Number	Depth in meters

APPENDIX 6. BASIC QUERY DESIGN FOR DATABASE EXTRACTIONS

EXAMPLE 1: SUMMARY OF OBSERVATIONS BY INTERACTIVE SELECTION OF EVENT CODES AND SET NUMBERS

```
set wrap off;
set linesize 100;
set pagesize 200;
column avtemp format 99.99;
column avdepth format 99.99;
spool c:\&filename;
```

rem Elapsed minutes by day are calculated by sub-stringing hours from the timestamp, multiplying by 60 then adding remaining minutes. Temp1 table contains a summary of depth and temperature by minute for each set rem

```
create table temp1 as
select location, setno, rdate,(to_number(substr(hhmiss,1,2))*60) +
to_number(substr(hhmiss,3,2)) minutes,
avg(depthm) depthm,avg(tempc) tempc
from remotetdr
group by location,setno,rdate,(to_number(substr(hhmiss,1,2))*60) +
to_number(substr(hhmiss,3,2));
```

rem Duration of set is calculated in Temp2 table by subtracting minimum elapsed minute from maximum elapsed minutes rem

```
create table temp2 as
select setno,max(minutes)-min(minutes) duration from temp1
group by setno;
```

rem Temp3 table contains a summary of all observations by set and location by joining Temp1 with remotecsv using set number and elapsed minute rem

```
create table temp3 as
select c.name,a.setno,a.key,a.observation,count(*) obs,avg(b.depthm)
avdepth,avg(b.tempc) avtemp
from remotecsv a,temp1 b,remoteinf c
where a.setno = b.setno
and b.setno = c.setno
and (to_number(substr(a.hhmiss,1,2))*60) + to_number(substr(a.hhmiss,3,2))
= b.minutes
group by c.name,a.setno,a.key,a.observation;
select * from temp3;
```

rem Partial output from this extraction rem

NAME	SETNO	KEY	OBSERVATION	OBS	AVDEPTH	AVTEMP
Flagg Cove	35	12	StartSet	1	28.63	16.20
Flagg Cove	36	0	Open	8	7.54	11.97
Flagg Cove	36	2	Crab	14	6.60	12.21
Flagg Cove	36	3	Uniqu	1	4.85	14.24
Flagg Cove	36	7	Mud	1233	5.11	12.92
Flagg Cove	36	8	Sand	196	6.76	11.99
Flagg Cove	36	10	EndSet	1	6.13	11.86
Flagg Cove	36	11	Hidden	1	7.10	12.08
Flagg Cove	36	12	StartSet	1	3.88	12.67
Flagg Cove	37	0	Open	55	11.65	11.74
Flagg Cove	37	1	Fish	2	10.51	12.97
Flagg Cove	37	2	Crab	5	10.96	12.32
Flagg Cove	37	7	Mud	9	3.80	16.24
Flagg Cove	37	8	Sand	611	11.44	11.97
Flagg Cove	37	10	EndSet	1	12.90	11.67
Flagg Cove	37	11	Hidden	12	11.44	11.97
Flagg Cove		12	StartSet	1	3.80	16.24
Flagg Cove	38	7	Mud	558	7.10	12.43
Flagg Cove	38	8	Sand	21	2.55	18.25
Flagg Cove	39	0	Open	44	10.99	12.34
Flagg Cove	39	2	Crab	26	11.19	11.83
Flagg Cove	39	7	Mud	49	5.34	15.00
Flagg Cove	39	8	Sand	1165	10.22	11.85
Flagg Cove	39	10	EndSet	1	11.60	11.82
Flagg Cove	39	11	Hidden	6	10.03	11.95
Flagg Cove	39	12	StartSet	1	11.08	13.64
Friars Bay	49	1	Fish	4	16.46	11.85
Friars Bay	49	2	Crab	4	16.44	11.84
Friars Bay	49	3	Unique	2	4.93	14.95
Friars Bay	49	7	Mud	490	10.25	12.18
Friars Bay	49	8	Sand	675	16.63	11.86
Friars Bay	49	10	EndSet	1	9.88	11.97
Friars Bay	49	12	StartSet	1	2.30	17.22
Friars Bay	49	13	Macroalga	58	4.53	14.71

rem This interactive query extracts summary data by prompting user for set numbers and desired events rem

```
column name format a12;
column observation format a12;
select
c.name,a.setno,c.observation,c.obs,b.duration,round(c.obs/b.duration*60)
obsperhour,c.avdepth,c.avtemp
```

```
from temp1 a, temp2 b, temp3 c
where a.setno = b.setno
and b.setno = c.setno
and c.key in (&keys)
and c.setno in (&setnos)
group by c.name,a.setno,c.observation,c.obs,b.duration,round(c.obs/b.duration*60),c.
avdepth,c.avtemp;
```

rem Output from this query for code 0 or "Open" lobsters for set 37 rem

```
Enter value for keys: 0
old   5: and c.key in (&keys)
new   5: and c.key in (0)
Enter value for setnos: 37
old   6: and c.setno in (&setnos)
new   6: and c.setno in (37)
```

NAME	SET NO	OBSERVATION	OBS	DURATION	OBSPER HOUR	AV DEPTH	AV TEMP
Flagg Cove	37	Open	55	21	157	11.65	11.74

```
spool off;
drop table temp1;
drop table temp2;
drop table temp3;
```

EXAMPLE 2: HOW DO YOU EXTRACT THE TYPE OF BOTTOM THAT WAS LOGGED IMMEDIATELY BEFORE AND AFTER A SELECTED EVENT ?

rem This query examines bottom 2 s before and after an 'Open' lobster event for set 37 rem

```
undefine setno;
undefine key;
create table test1 as
select hhmiss from remotecsv where setno = &&setno
and key = &&key
order by hhmiss;
select a.hhmiss + 2, a.observation from remotecsv a, test1 b
where a.hhmiss = b.hhmiss
and a.setno = &setno
and key <> &key;

select a.hhmiss – 2, a.observation from remotecsv a, test1 b
where a.hhmiss = b.hhmiss
```

```
and a.setno = &setno
and key <> &key;
drop table test1;

SQL> start c:\remote\nextdoor.txt;
Enter value for setno: 37
old   2: select hhmiss from remotecsv where setno = &&setno
new   2: select hhmiss from remotecsv where setno = 37
Enter value for key: 0
old   3: and key = &&key
new   3: and key = 0

Table created.

Old   3: and a.setno = &setno
new   3: and a.setno = 37
old   4: and key <> &key
new   4: and key <> 0
```

rem Output reveals that a sand bottom type prevailed rem

```
A.HHMISS+2 OBSERVATION
   141814 Sand
   141956 Sand
   142016 Sand
   142034 Sand
   142048 Sand
   142106 Sand
   142136 Sand
   142144 Sand
   142154 Sand
   142206 Sand
   142210 Sand

   A.HHMISS-2 OBSERVATION
   141810 Sand
   141952 Sand
   142012 Sand
   142030 Sand
   142044 Sand
   142102 Sand
   142132 Sand
   142140 Sand
   142150 Sand
   142202 Sand
   142206 Sand
```

APPENDIX 7. RETRIEVAL OF VIDEO

To demonstrate retrieval of specific video for a given time period, area and event, the following query and output are listed. An investigator wishes to search for lobster distribution in a small region of Long Island Bay near Grand Manan during the month of September in 2002. The task is to query the Remoteinf table to set the time window, and join against the Remotecsv table to set the geographic window for lobsters logged in the "Open".

```
SQL> r
  1  select b.rdate,b.tapenumber tnum,b.tapelocation tloc,
  2  a.setno,a.hhmiss time,a.lat,a.lon
  3  from remotecsv2 a,remoteinf b
  4  where a.lat between 44.7481 and 44.7488
  5  and a.lon between 66.7510 and 66.7516
  6  and a.key = 0
  7  and to_char(b.rdate,'mm') = 09
  8  and to_char(b.rdate,'yy') = 02
  9* and a.setno = b.setno
```

The query confirms that video footage is available at the times indicated for set 24 on tape #18.

RDATE	TNUM	TLOC	SETNO	TIME	LAT	LON
04-SEP-2002	18	248	24	155242	44.74869	66.751508
04-SEP-2002	18	248	24	155128	44.74853	66.751378
04-SEP-2002	18	248	24	155026	44.74842	66.75128
04-SEP-2002	18	248	24	154850	44.74821	66.75114

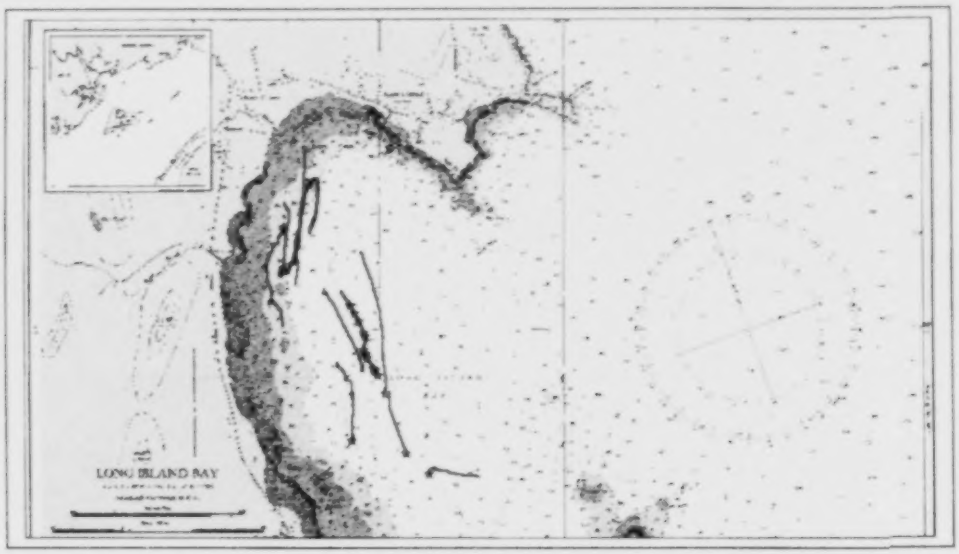


Fig. 7A: A Mapinfo GIS workspace reveals the tracks for all sets performedl on Sepember 4, 2002 in the Grand Manan area.

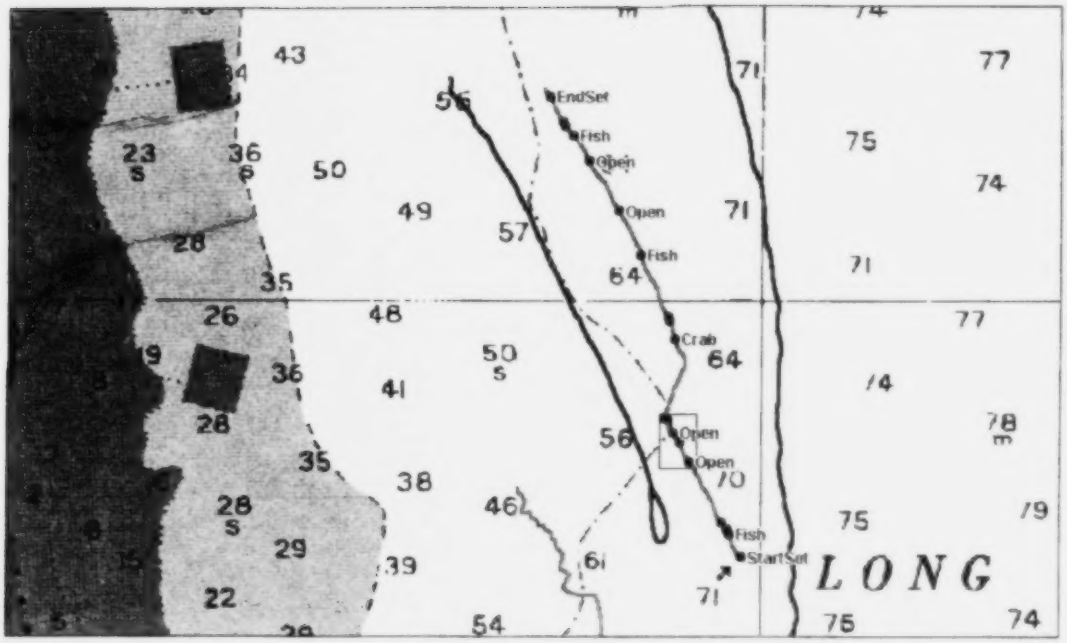
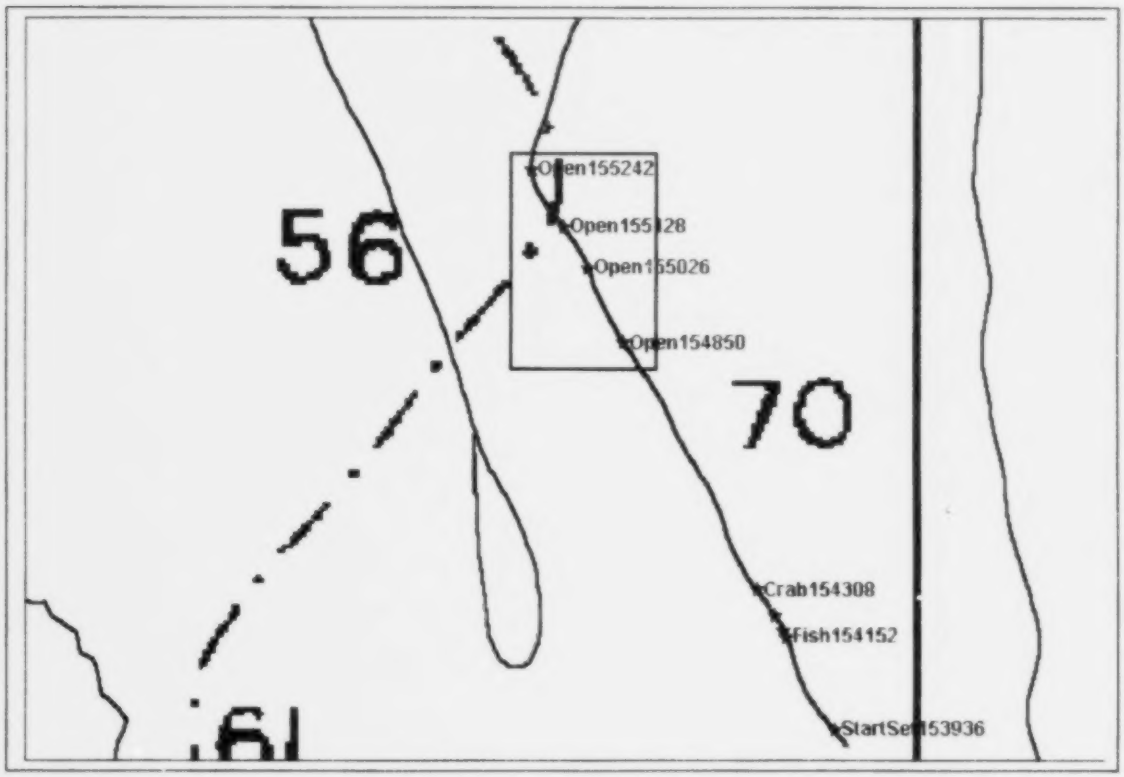


Fig. 7B: The geographic window defined within the query is depicted in a closer view above. The selection window intersects the track of set 24, and the location of the lobsters foraging in the "open" appear as they were logged .



16
3
6
23
36
50
13
28
35
7
17
26
19
36
8
28
35
2
16
28
8
29
15
22
LONG

56
70
61

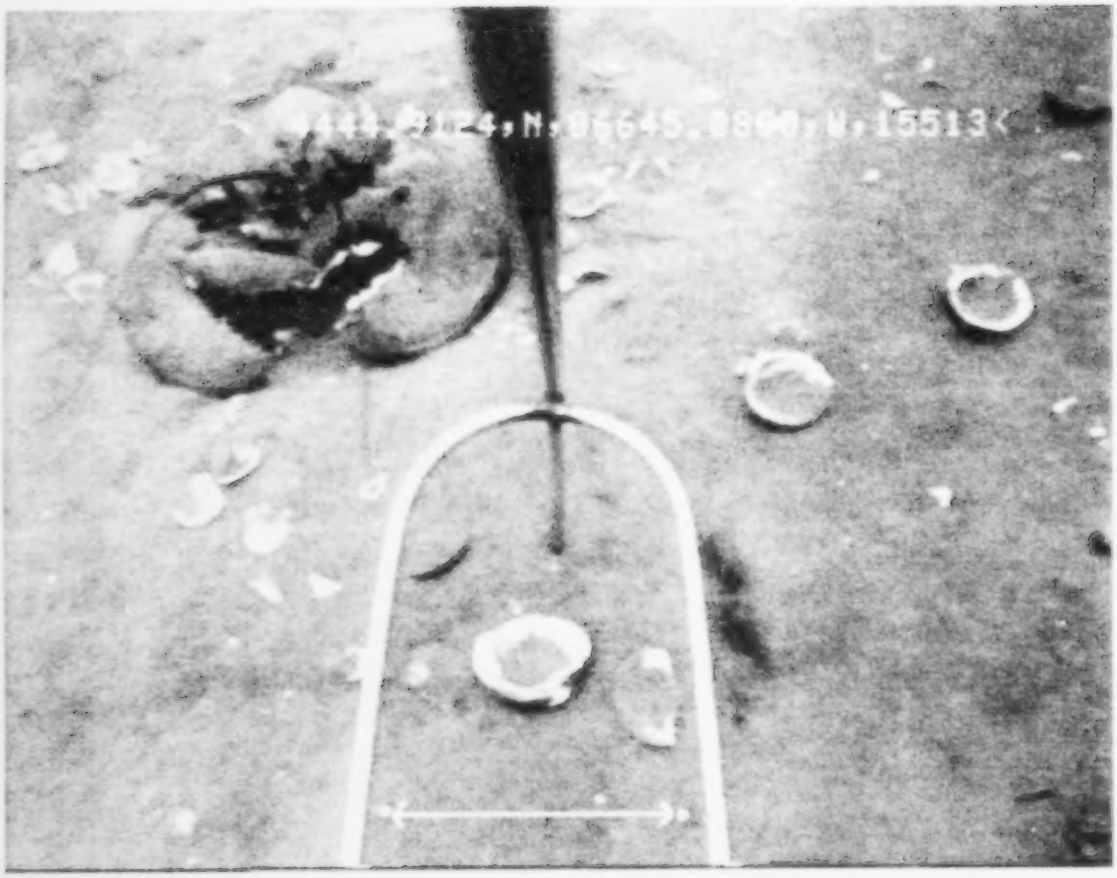


Fig. 7D: Tape 18 is retrieved, and advanced to the selected times extracted in the query. The frame above reveals one of the lobsters as it appeared 2 s after it was logged at 15:51:28 on Set 24, September 4, 2002. Note twin laser dots spaced at 25 cm visible between the camera frame.